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Increasing the lifetime of mobile sink using virtual grid in wireless sensor networks with dynamic route adjustment scheme

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ABSTRACT

The wireless sensor network has emerged as a new information-gathering paradigm in a wide range of applications, such as health care, outer-space exploration, battlefield surveillance, and emergency response. Before monitoring the environment, the sensor nodes must be able to discover nodes and organize themselves into a network. Most of the energy of the sensor is consumed on sensing the field and uploading data to the data sink. Energy consumption on sensing is stable because it depends on the sampling rate and it does not depend on the network topology or the location of the sensors. The data-gathering scheme is the most important factor that determines the network lifetime. Virtual Grid based Dynamic Route Adjustment (VGDRA) is proposed for periodic data collection from WSN. Unlike the existing solutions, it increases the data delivery performance by employing multiple mobile sinks or by deploying super nodes at strategically important points in the sensor field. It aims to minimize the trade-off between nodes energy consumption and data delivery VGDRA scheme for mobile sink based WSNs performance using a single mobile sink while adhering to the low-cost theme. The VGDRA scheme enables sensor nodes to maintain nearly optimal routes to the latest location of a mobile sink with minimal network overhead.

Keywords: Mobile sink, dynamic route adjustment, wireless sensor networks, data gathering and energy consumption

1. INTRODUCTION

The main objective of this paper is to minimize the energy conservation of sensor network. Wireless sensor network is a group of specialized transducers with a communication infrastructure intended for monitoring and record conditions at diverse locations. It monitors the temperature, sultriness, pressure, wind direction and speed, illumination intensity, vibration intensity, sound intensity, power-line voltage, chemical concentrations, pollutant levels and vital body functions. The sensor nodes operate in the three modes: sensing, computing and communications. The sensing unit is entrusted with the responsibility to detect the physical characteristics of the environment and an energy consumption that varies with the hardware nature and applications. The communication unit consists of a short-range circuit which performs the transmission and reception tasks. The energy contributes to data forwarding and it is resolute by the transmission range that increments with the signal propagation in an exponential way. Some of the energy conservation approaches as follows.

2. RELATED WORKS

Hamida et al [4] presented a vertical virtual line of width divides the sensor field into two parts and this line is also divided into groups of size and it is placed at the center. So any node can easily access it nodes that are in these boundaries are inline nodes and other are ordinary nodes. This line acts as region for data storage and lookup. In dissemination, ordinary sensor nodes send new data to the nearest inline node. To retrieve specific data, sink sends query toward the line in a perpendicular fashion. The first inline node that receives the data will propagate in both directions until it reaches an inline node storing the data. The data are then sent directly to sink. The nodes can easily access the line and structure is constructed with low overhead. In large networks, energy consumption increases because of flooding on the line. Guo-He Ye et al [3] proposed a hierarchical role based data dissemination approach, for large scale wireless sensor networks with multiple mobile sinks. In HRDD, it uses a hierarchical cluster-based structure to discover and maintain the routing paths for distributing data to the mobile sink. There are two roles, named Indexing Agent and Gateway Agent, to some sensor nodes in the wireless sensor networks. Indexing Agents are used to remove unnecessary query messages, while gateway agents contribute to decrease energy consumption and the broadcasting messages. HRDD evaluates and compare the impact of the number of nodes with prior approach. The simulation results justify that HRDD has the capability to reduce the energy consumption in the wireless sensor networks and to prolong the network lifetime.

Oh et al [6] proposed a communication protocol to support sink mobility without global position information. To reduce the number of cell headers, we consider multi-hop clusters. Also, to avoid the location registration of a mobile sink to the whole cell headers, we use a rendezvous cell header on which queries of the mobile sink and reporting data of a source node meet. However, such a manner also has a data detour problem that the source node sends data packets to the mobile sink via the rendezvous cell header. Thus, a scheme is presented to find a path with less hop counts between cell headers where the source node and the mobile sink are located in. Simulation results show that the proposed protocol is superior to the existing protocols in terms of the control overhead and the data delivery hop counts. Erman et al [2] addressed the data delivery to mobile sink and source event dynamic conditions hexagonal grid structure is constructed. Nodes send data which forwards towards the center cell from the nearest border line. The data will be stored and replicated at the nodes which are on the border line. Sink sends queries towards the center cell and after reaching particular border line node that considers data it sends in reverse path. When sink moves, it informs to both border nodes and center nodes along the route. The border line cells and center cells result in more energy dissipation. Tang et al [7] created a virtual strip in the middle of the sensor field, thereby placing enhanced wireless nodes having more storage capacity at equal distances. The set of sub-sink nodes along the accessible path serve as rendezvous points for the mobile sink and collect and store data from sensor nodes. In data delivery phase, mobile sink floods the query along the virtual strip till it reaches to the sub-sink node owning the data. Upon receiving the query from mobile sink, the sub-sinks route their deposited data to the mobile sink using geographical forwarding approach.

Chen et al [1] discussed about the virtual circles and straight line is used for virtual structure construction. The virtual backbone network is formed by a set of cluster head along with straight lines and virtual circles. For data collection sink moves around with straight lines and virtual circles. For data collection sink moves around the sensor field and communicates with cluster heads, which are on the border. The cluster heads minimize route readjustment by following a set of rules. The cluster head depletes its energy, fast because it is placed at the center of the sensor field and also mainly involve in route readjustment. Khan et al [5] proposed a virtual grid of uniform size cells is formed by partitioning the sensor field and the nodes closest to the center of the cell are appointed as cell headers. Nodes other than cell headers report data to cell headers. Cell header; adjust the routes based on the

propagation rules for sink mobility. Mobile sink moves around the sensor field to collect data periodically. The disadvantage of this scheme is certain cell headers take long route to deliver the data to mobile sink this increases energy consumption.

3. EXISTING SYSTEM

In the existing system, static node deployment where nodes exhibit n-to-1 communication in reporting their observed data to a single static sink, gives elevate to the energy aperture phenomenon in the vicinity of the sink [8]. To cope with the dynamic network topology, nodes need to keep track of the latest location of the mobile sink for efficient data distribution [13]. Some data dissemination protocols, e.g. Directed Diffusion (DD) proposes periodic flooding of sink's topological updates in the entire sensor field which gives elevate to more collisions and thus more retransmissions which undermines the energy conservation goal [9]. Sink mobility causes dynamic network topology and thus each sensor node in the sensor field have to readjust their routes towards the latest location of mobile sink which leads to more route reconstruction cost [10,14]. Exploiting the sink's mobility avails to protract the network lifetime, thereby alleviating energy-aperture quandaries [12,15]. In the virtual infrastructure predicated data dissemination schemes, to minimize the energy consumption of each individual node only a set of designated nodes scattered in the sensor field is responsible to keep track of sink's locations such designated nodes amass the observed data from the nodes in their vicinity during the absence of the sink and then proactively or reactively report data to the mobile sink [11]. In order to minimize the route reconstruction cost only a inhibited number of cell-headers precedent originating cell header and downstream of originating cell header take part in the routes re-adjustment process.

4. PROPOSED SYSTEM

4.1. Proposed system architecture

VGDRA enables sensor nodes to maintain nearly optimal routes to the latest location of a MS with minimal network overhead. It partitions the sensor field in a virtual grid of equal sized cells and constructs a virtual backbone network comprised of all the CH. Nodes close to the center of the cells are appointed as CHs, which are responsible for data collection from member nodes within the cell and delivering the data to the MS using the virtual backbone network. The goal behind such virtual structure construction is to minimize the routes re-adjustment cost due to sink mobility so that the observed data is delivered to the MS in an energy efficient way. In addition, VGDRA also sets up communication routes such that the end-to-end delay and energy cost is minimized in the data delivery phase to the MS. The MS moves along the periphery of the sensor field and communicates with the border CHs for data collection. Using VGDRA, only a subset of the CHs needs to take part in re-adjusting their routes to the latest location of the MS thereby reducing the communication cost. Simulation results reveal decreased energy consumption and faster convergence of VGDRA compared to other state-of-the art. The architecture diagram of VGDRA is as shown in Figure 4.1.

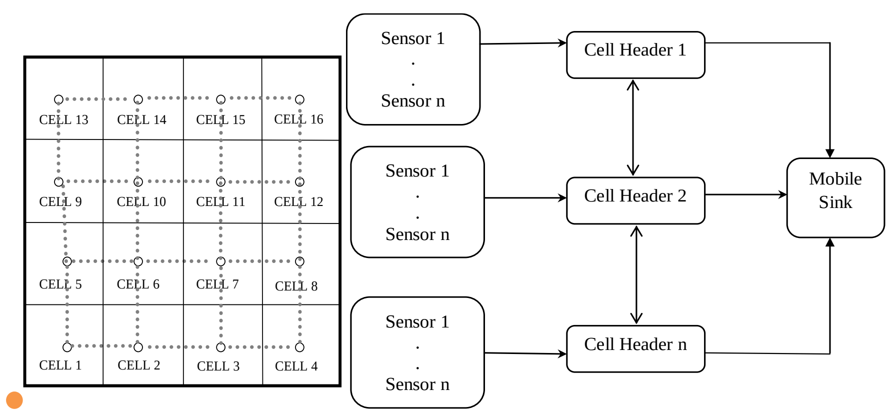

Figure 4.1 Architecture diagram of VGDRA

4.2. Module description

4.2.1. Virtual structure construction

The virtual grid structure is formed by partitioning the sensor field into uniform sized cells based on the number of nodes. The partitioning of sensor field is taken because of uniform workload on the part of CH nodes which expand the network lifetime. Cell size is partitioned from sensor network such that it should satisfy the range in between sensor node minimum range and sensor node maximum range as mentioned in the Table 4.1.

Table 4.1 Network partition

No. nodes (N)	Minimum and Maximum Range for CH Selection	No. CHs (K)
100	$1 < N\times0.05 \le 6$	4
200	$6 < N\times0.05 \le 12$	9
300	$12 < N\times0.05 \le 20$	16

VGDRA elects CH in every cell, i.e. the node which is closest to the midpoint of the cell. The total number of nodes computes the midpoints of all the cells by the sensor field's dimension knowledge. In election process to reduce communication cost, the nodes whose distance to the midpoint of the cell having less threshold will only take part in the election. The threshold distance may increase during the election process if no node is found within the threshold distance. This election strategy helps in energy conservation and also elects CH at the appropriate position within the cell. CH shares its status within the cell and slightly outside the cell boundary. Nodes associate themselves to the closest one when it receives notification from more than one CH. Nodes when receive multiple notifications it shares information to primary CH about the secondary CH. In this way, neighboring CHs form adjacencies using gateway nodes. The maximum CHs adjacent for the border line CH are 2, 3 whereas for an inside CH is 4. The virtual backbone structure type was formed by the set of CH nodes together with the gateway nodes as shown in Figure 4.2.

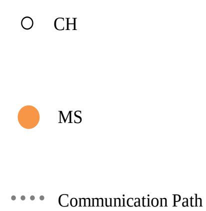

Figure 4.2 Virtual structure after establishing adjacencies

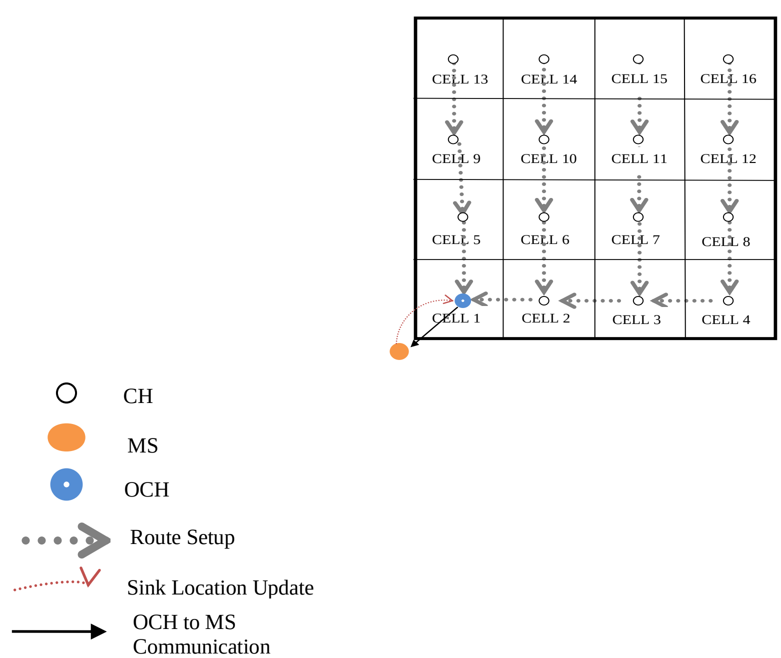

Figure 4.3 Virtual structure after initial route setup

Now consider the sink is at coordinates (0, 0) communication routes are set up. The CHs adjust their routes to the MS initial position based on the communication routes set up. Figure 4.3 shows the virtual backbone structure when the sensor field is partitioned into 16 cells and after the initial routes set up.

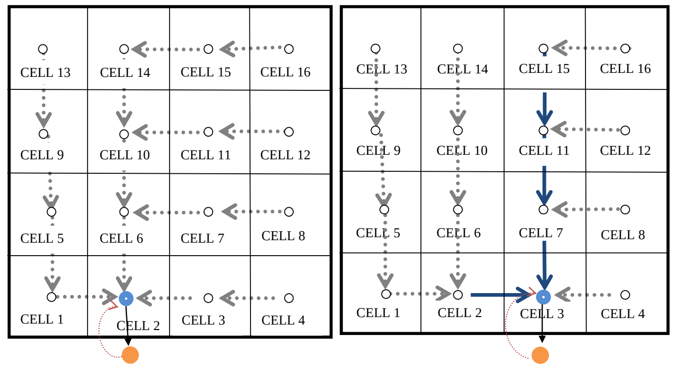

Figure 4.4 Route re-adjustment

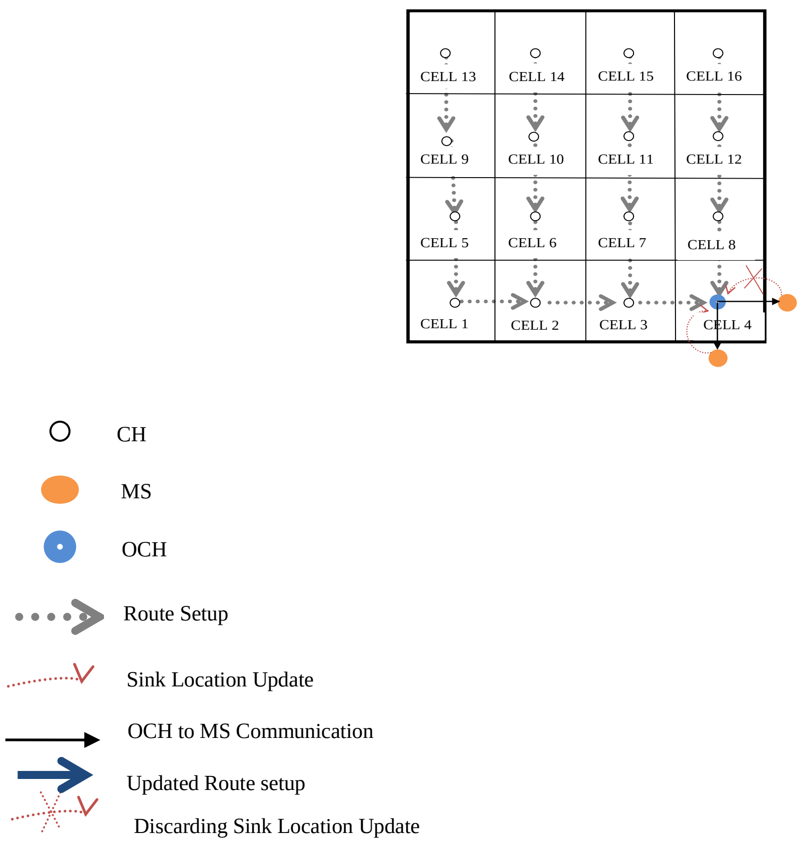

Figure 4.5 Preventing the undesired propagation of sink location updates

4.2.2. Dynamic route adjustment scheme

The VGDRA scheme defines a set of propagation rules for CHs take part in the routes re-adjustment process is explained as follows,

Rule 1: The Originating Cell Header (OCH) upon sink discovery first verifies whether its next-hop is already set in the MS. If the MS was previously being set up as its next-hop, the OCH does not propagate sink's location update. Else the next-hop entry of the OCH is other than the MS it exercises Rule 2.

Rule 2: The OCH begin one hop from the MS sets the MS as its next hop and share this information with the previous OCH and its downstream adjacent CH.

Rule 3: The previous OCH upon receiving the sink's location update from the current OCH adjusts its data delivery route by setting the current OCH as its next-hop towards the sink.

Rule 4: The downstream CH upon receiving the sink's location update checks whether the sender CH is the same as its previous next-hop or different. If it is the same, the downstream CH drops the sink's location update packet and does not propagate it further to the next downstream CH. In the case when it is different, the downstream CH updates its next-hop entry to the new sender CH and further propagates the sink's location update to the next downstream.

Figure 4.4 shows an example of the data delivery paths when the sink is located in the cell 2 premises. When the mobile sink moves from cell 2 to cell 3, the cell-header at cell 3 exercises rule 2 and rule 3 to update the cell-header at cell 2, followed by rule 4 to update its downstream cell-headers as shown in Figure 4.4. In this way, only a limited number of CHs take part in the routes re-adjustment process, thereby reducing the overall routes re-adjusted cost of the network. Similarly, Figure 4.5 demonstrates when the mobile sink moves within the same cell, the cell-header at cell 4 exercises rule 1 and refrains itself from propagating sink's location information. This strategy helps to minimize the routes reconstruction cost to a great extent and thus improves the network lifetime.

4.2.3. CH rotation

The CH being the local data collector is vulnerable to high energy dissipation and therefore to prolong the network lifetime, the CH role needs to be distributed among the nodes within the cell. In order to achieve uniform energy dissipation, the VGDRA scheme keeps track of the residual energy level of the current CH, where if it gets below a certain threshold, the new CH election is initiated by the current CH. In the re-election process, the node that is relatively closer to the midpoint of the cell and has a higher energy level compared to other candidates is elected as the new CH. In order to preserve the virtual backbone structure, the current CH before stepping down, shares the information of the new CH not only with all its member nodes but also with the adjacent CHs in its neighborhood. The data flow diagram for CH rotation is mentioned in the Figure 4.6.

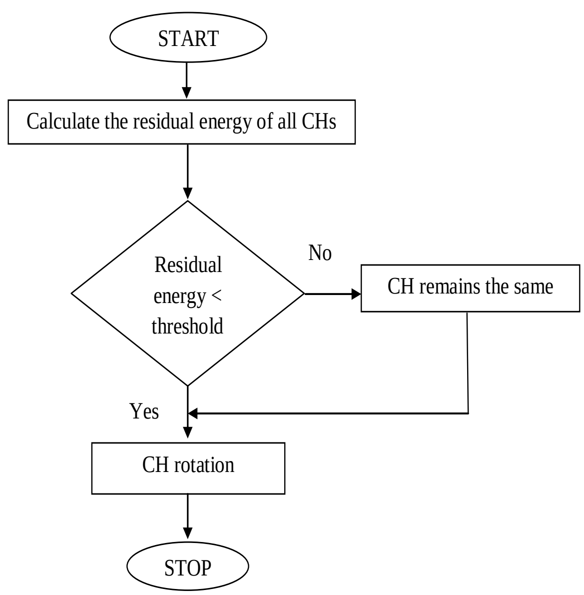

Figure 4.6 Data flow diagram for CH rotation

5. PARAMETER EVALUATION

VGDRA scheme is compared with VCCSR were a common feature between them is the use of a virtual infrastructure for network operation. Here three different criteria to evaluate the performance of the VGDRA against VCCSR scheme.

Energy

Figure 5.1 represents the comparison between Nodes and Energy. Nodes using VGDRA scheme incur less energy compared to the VCCSR scheme because of taking the nodes within the shortest distance to the midpoint of the cell for CH election. The VGDRA scheme, using the average node energy consumption in reconstructing the data delivery routes to the latest location of mobile sink.

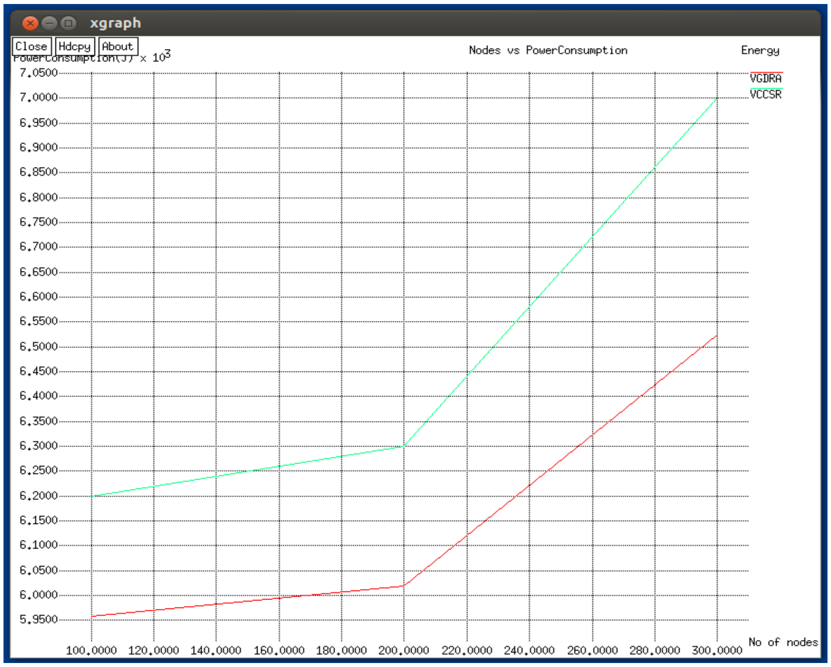

Figure 5.1 Comparing the energy efficiency for different network sizes

Packet delivery ratio

Figure 5.2 indicates the packet delivery performance. The packet delivery ratio can be calculated as the ratio between transmitted and received for overall packets. VGDRA algorithm and VCCSR are compared with node variation. When sensor nodes increased from 100 to 300 nodes in the environment, the packet delivery ratio is decreased in both the algorithms.

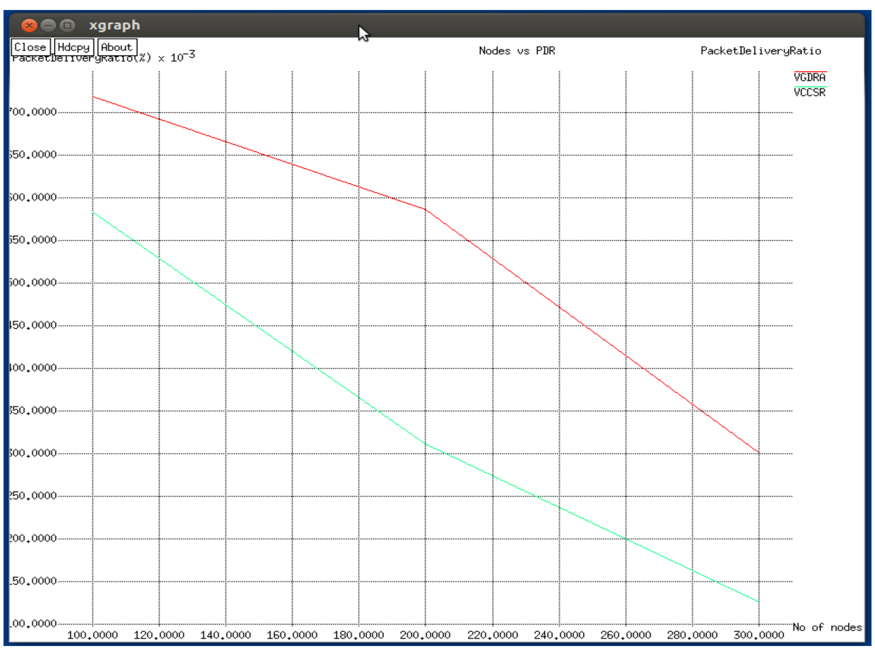

Figure 5.2 Comparing the packet delivery for different network sizes

Delay

The delay time is an indirect reflection of the data delivery efficiency as the more promptly the nodes come to know about the latest location of a mobile sink, the most efficient routes they can select in disseminating the sensed data. Figure 5.3 represents the delay time of the VGDRA is minimum compared to VCCSR when the sink is moving at a speed of 10 m/s.

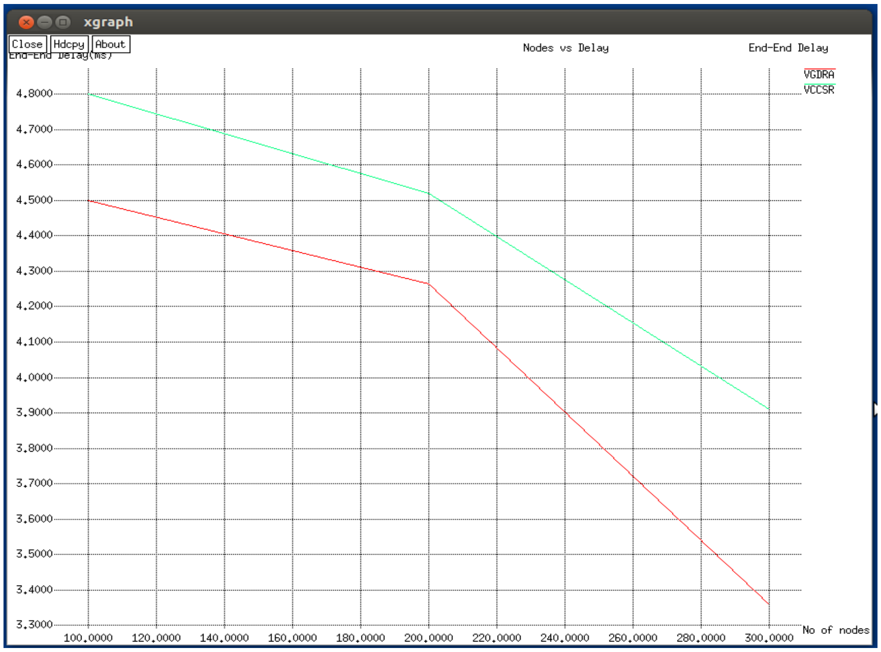

Figure 5.3 Comparing the delay time for different network sizes

6. CONCLUSION

Virtual Grid based Dynamic Routes Adjustment (VGDRA) scheme that incurs least communication cost while maintaining nearly optimal routes to the latest location of the mobile sink. In VGDRA scheme partitions the sensor field in a virtual grid and constructs a virtual backbone structure comprised of the CH nodes. A mobile sink while moving around the sensor field keeps on changing its location and interacts with the closest borderline CH for data collection. Using a set of communication rules, only a limited number of the CHs take part in the routes reconstruction process thereby reducing the overall communication cost. In terms of nodes energy consumption, the simulation results reveal improved performance of our VGDRA scheme for different network sizes. Considering the scope of this project, the actual data delivery model is not included. In future work, to analyze the performance of the VGDRA scheme at different sink's speeds and different data generation rates of the sensor nodes. The proposed VGDRA scheme though offers a lightweight solution and does not impose many constraints on part of the resource constrained sensor motes, yet its practical implementation on real hardware needs to be confirmed.

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